Safety Guidelines for the Design of Vehicular Mounted Communications-Electronics Systems Using On-Board Power

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Safety Guidelines for the Design of Vehicular-Mounted
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Abstract

The purpose of this paper is to provide a reference for engineers on how to safely integrate on-board power with vehicular-mounted electronics system. This paper focuses on military applications, though the guidelines can be applied to any commercial mobile electronics suite with its own power source. The scope of the paper includes a discussion of the types of on-board power, wiring for safe grounding, engine control considerations, and a review of potential health hazards. The objective is to present a guide for the safe design of such systems that can be used to eliminate the recurring design flaws seen in these systems. The information contained in this paper is applicable to various industries and will provide operational advantages by improving the safety of vehicular-mounted electronics systems.

Introduction

The Army of today must be able to deploy more rapidly than ever. In general the less equipment needed to be deployed, the quicker the deployment. To aid in reducing the amount of hardware needed to operate Communications-Electronics (C-E) systems, and to make systems less reliant on other systems, on-board power has become very popular. On-board power eliminates the need for a separate generator, or commercial power. By using on-board power, systems are more independent and take up less shipping space.

Types of On-Board Power

Generators: The first type of on-board power commonly used is the on-board generator. These generators typically have their own engines that draw fuel from the prime mover's fuel tanks. Typically these generators only supply AC power directly, but on some systems a DC generator is also included. Generators usually supply more power than other forms of on-board power. However, generators are larger and heavier than other power options.

Alternators: Another frequently used method for generating power is the use of a high current output alternator driven by the prime movers' engine. These alternators typically produce 200 to 400 amperes at 28 volt DC. The DC power is then passed through invertors to produce AC power when necessary. Alternators are convenient since they do not require a secondary engine to produce the needed power. The limitation of alternators is their power availability, and the extra wear on the prime mover's engine.

Power Take-Off (PTO) Generators: PTO generators are similar to alternators in that they use energy produced by the prime mover's engine to generate power. They divert the energy at the engine's drive shaft to turn a generator. This type of generator is not used as frequently as alternators and generators, because they require more extensive modifications to the prime mover.

Battery Banks: When power demands are not large, batteries can be used to provide power to equipment. These batteries can either be the same batteries that are used to power the vehicles electrical system, or they could be dedicated to the equipment on-board. These battery banks may provide DC power alone, or they could pass the DC current through invertors to convert it to AC. When the vehicle engine is running, and power is being supplied by the vehicle's main batteries, the situation is the same as described above under alternator power. If the vehicle is not running or if a dedicated battery bank is used then the power limitations are based on the charge of the battery. Discharging the vehicle battery is a potential undesirable affect of this type of power.

Combinations: Combinations of the above mentioned sources and external power, commonly called shore power, can make a system more robust. Shore power can be used when it is available reducing wear on the system. Multiple on-board sources can also improve the systems reliability. The problem with using a combination of power sources is that the systems are often not wired correctly.

Wiring for Electrical Safety

Systems with on-board power sources have unique considerations with respect to wiring for electrical safety. The key element to electrical safety is the grounding system.

Grounding System Components: Grounding is often a misunderstood principle of electrical wiring. There are three essential components to a grounded system, the equipment grounding conductor, the system bonding jumper, and the grounding electrode conductor (Ref. 1). Each of these conductors plays an essential role in ensuring a system is grounded (see figure 1).

Equipment Grounding Conductor (EGC): The EGC also known as the ground wire, the green wire, or the safety ground, provides a connection that electrically bonds all pieces of equipment in the system together. This conductor, as with all the conductors in the grounding system, is not intended to normally carry current. Its purpose is to ensure all pieces of equipment are at the same potential, and to provide a low enough impedance path back to the source to trip the circuit breaker in the event of an electrical fault. For vehicular mounted systems it is always best to run a dedicated EGC rather than relying on the vehicle chassis to perform this function. First, the EGC when run with the phase and neutral conductors will have a lower total impedance. Second, many of the modern vehicles being used do not have a good electrically continuous chassis and body, meaning that the resistance between two points on the chassis or body may be high.

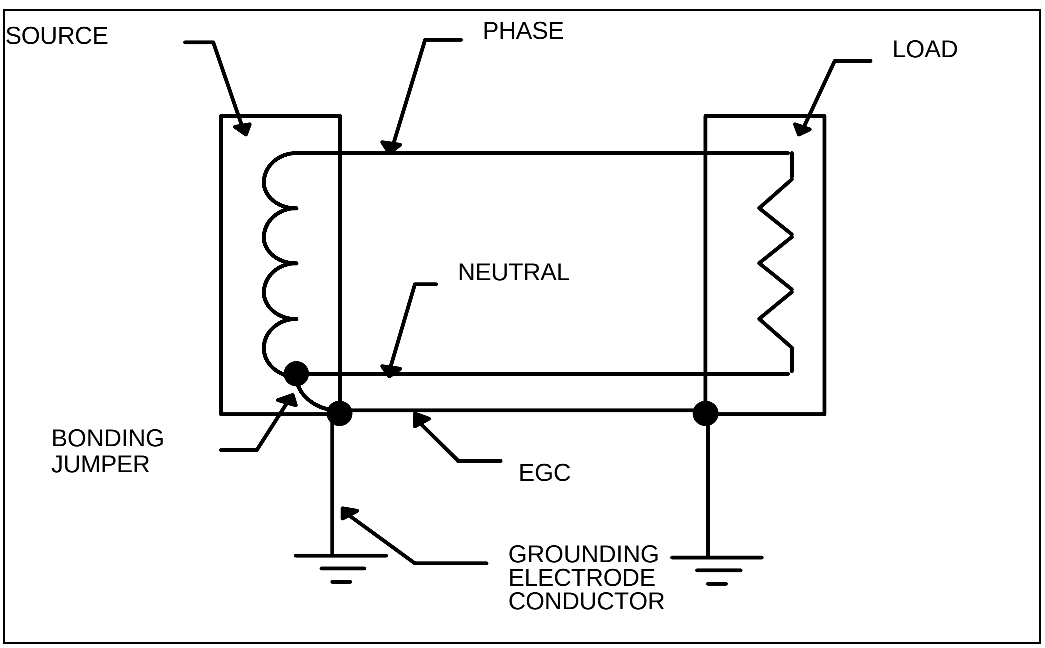

Figure 1 Grounded System Components

System Bonding Jumper: The system bonding jumper connects the EGC to the neutral wire, or grounded conductor. Without this jumper the fault current could not flow from the EGC back to the source and trip the circuit breaker.

Grounding Electrode Conductor: The grounding electrode conductor, commonly referred to as the ground strap, connects the shelter, generator, or other power source to the ground rod in the earth. This bond to the earth can then be used as a redundant return path in the event the EGC is damaged. It also is used to discharge external voltages that may have gathered on the system such as lightning, contact with a power line, or static electricity.

Special Wiring Considerations for Systems Using On-Board Power

Systems Using On-Board Power Only: Systems that use only on-board power should contain all of the components of the grounding system except possibly the grounding electrode conductor. This means that the neutral and EGC should be tied together with the bonding jumper as close as possible to the generating source. In the case of a self contained system the purpose of the grounding electrode conductor is to discharge objectionable external voltages like lightning and other stray voltages. When mission constraints allow it is always a good idea to have a grounding electrode conductor attached to a ground rod. This becomes particularly important if the system has a mast that will remain raised for extended periods of time. A grounding electrode should also be driven any time the system will be interconnected with other systems. In this case the grounding electrode is used to clear surges that enter the system via the interconnecting cabling.

Systems Using a Combination of Power Sources: The use of more than one power source as an option to power the system is a good design practice. It provides system flexibility and reduces wear on the on-board power source. However, the use of multiple power sources requires a more sophisticated ground wiring schematic to insure the system is adequately grounded.

The most misunderstood part of wiring for systems using multiple power sources is the use of the system bonding jumper. The system should be wired such that when on-board power is being used the system bonding jumper is connected as close as possible to the generating source. When external power is used the system bonding jumper should be located only at the external source. This means that the system design must isolate different power source ground-neutral bonding points. Connection of the system bonding jumper at both the mobile system and the external source can cause several problems. First, a ground loop will occur that could cause objectionable electronic noise in the system. Ground loops can cause conductively coupled interference from lower frequency noise currents flowing in the ground wire (Ref. 2). Second, the EGC and the neutral are now essentially the same conductor. There is no longer a dedicated grounding conductor without current flowing on it. Because current is flowing across the EGC that has a finite resistance, the mobile system will no longer be at the same potential as ground. While this potential may not be high enough to cause a serious shock hazard to personnel, it could cause damage to sensitive pieces of external electronic equipment connect to the system. Third, under a bolted fault extremely high current levels can flow for a brief time. Such current levels can generate a substantial voltage on the enclosure. Though the developed voltage exists for a very brief time, long or kinked cables could provide enough resistance to raise voltages to a level that could initiate cardiac arrest.

To eliminate the situation described above there is a simple design solution. The switch that is used to determine which source will power the system should be designed to switch between the neutral source as well as the phase sources. The system bonding jumper should then be attached on-board as close as possible to the on-board generating source. The external source should likewise have the system bonding jumper located as close as possible to the generating source, or in the case of commercial power at the main service disconnect. Figure 2 illustrates how the system could be wired if one on-board power source is available and one external power source is available. If more than one on-board source is available, each source should have its own bonding jumper and its neutral conductor should be switched as well (Ref. 1). This will ensure the bonding jumper is located as close as possible to the generating source.

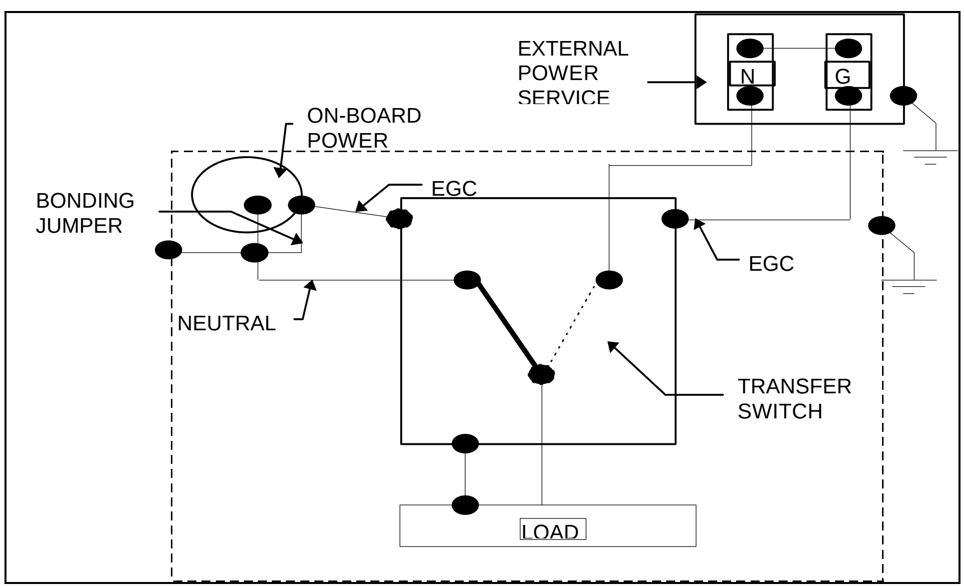

Figure 2. Proper Wiring of Neutral

Another item to consider is proper wiring for multiple DC sources for a DC powered system. The most important precaution to be aware of when designing for multiple DC power sources is that each power source must be provided with a circuit breaker, and reverse polarity diode protection. These items are needed to ensure one power source does not end up charging the other, and to prevent equipment damage caused from a source being hooked up with reverse polarity.

Engine Control Considerations

Another design consideration is the control of the engine that drives the power source. Since this engine may be a vehicle engine, and it may not have been originally designed to operate as the prime power source for an alternator, or generator, some special considerations are necessary.

Engine Status: It is important that data such as oil pressure, engine temperature, and fuel levels be provided to the operators. This is particularly important if the operators are not to remain in the cab of the vehicle during operation. The status of such items can be passed to the operator either by a status panel located near the operator, or if computers are to be used, by a pop up window on a workstation screen. Since the equipment operator may have a number of tasks to pay attention to, it is recommended that these indicators be accompanied by audio and visual alarms.

Governors: If a vehicle engine is used as the prime mover for the generator, or alternator, a governor may be necessary. When the load is removed from the engine, its RPMs may rise dramatically. A governor should be used to prevent this rise in RPMs from damaging the engine.

Design Considerations to Minimize Health Hazards

Systems using on-board power typically have additional potential health hazards. If these potential health hazards are kept in mind during the system design, they can be minimized or eliminated.

Noise: Since most of the on-board power sources require the use of an engine running at substantial RPMs there is often considerable noise involved in this type of operation. When the vehicle engine is used to generate the power it can be very difficult to reduce the noise levels in the area where the operator is seated. The primary means of reducing such noise should be through the use of sound attenuating materiel around the engine compartment, or around the enclosure where the operator is seated. Such items as noise attenuating and active noise reduction (ANR) headsets can also be used to reduce the noise to the operators. This personal hearing protection method should be used only as a last resort since it does not protect observers or maintenance personnel who may not have access to such devices.

Another means to reduce noise is by minimizing the vibration transferred between the engine and the enclosure. Low frequency shock isolators should be used to minimize vibration and reduce the resulting noise when possible.

Exhaust Emissions: Sheltered systems that use diesel, or gasoline engines to provide power can encounter problems with exhaust emissions contaminating the operator's enclosure. If the system is to remain stationary for periods of time with the engine running this can be a serious concern. To minimize this concern the following precautions can be taken.

Ventilation: Fresh air ventilation is necessary for systems that are enclosed. Typically this ventilation is necessary to replenish the oxygen supply, and to eliminate respiratory products such as carbon dioxide. MIL-STD-1472D (Ref. 3) can be used as a guide for determining how much fresh air is necessary. The quality of the fresh air brought in is important for keeping the air quality inside the system good. Careful consideration must be given to the relative location of the fresh air intake with respect to the engine exhaust. The fresh air intake should be placed as far away from the engine exhaust as practical to minimize the chance of drawing engine exhaust into the enclosure.

Exhaust Diversion***:*** An option to reduce the chance of engine exhaust being drawn into the enclosure is to divert the exhaust away from the vehicle. This may be necessary even if the ventilation fresh air intake is place far away from the exhaust. Often shelters are not well sealed and exhaust accumulation under the vehicle can seep into the enclosure. The exhaust can be diverted by placing an exhaust extension hose on the exhaust pipe. This option should be used with great caution. Exhaust pipes can get very hot. The material that the extension hose is made of must be able to withstand the heat produced by the exhaust pipe and be capable of being removed without burning the operator.

Air Sampling: To be sure that the design is safe for occupants air samples should be collected. For diesel engines these air samples should be analyzed to determine if such chemicals as carbon monoxide, carbon dioxide, nitrogen oxide, nitrogen dioxide, formaldehyde, and acroline are below permissible levels. Permissible levels can be found in the OSHA General Industry Air Contaminants Standard (Ref. 4), and the American Conference of Governmental Industrial Hygienists Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices (Ref. 5).

Conclusions

Many engineers enter into the design of a system using on-board power without considering all the necessary criteria. The design often centers around ensuring enough power can be generated, and little thought is put into proper ground wiring, engine status, and health hazards. This paper has provided a list of some of the criteria that must be considered when designing such a system. There are other issues and criteria that are not covered in this paper. The items discussed in this paper are those that the author has seen repeatedly overlooked by engineers. When these criteria are included in the design from the beginning it will save the program time and money as well as make the system safer for the user.

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Biography

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Mr. Vondera holds a Bachelors of Science degree in Electrical Engineering from the University of Missouri - Rolla, a Masters of Science degree in Industrial Engineering from Texas A&M University, and is a graduate of the Safety Engineering Program from the Army's School of Engineering and Logistics. He is a Certified Safety Professional. He is currently a safety engineer employed by the U.S. Army Communications-Electronics Command Safety Field Office at Vint Hill Farms Station, Warrenton, Virginia.